Healthy Chair

ECE 445 Design Document

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1. Introduction

1.1 Objective

The majority of the population sits for most of the day, whether it is students doing homework or employees working at a desk. In particular, during COVID-19 pandemic where many people are either working at home or quarantining for long periods of time, they tend to work out less and sit longer, making it more likely obesity, hemorrhoids, and heart diseases will result in people [1]. In addition, sitting too long is detrimental to one's bottom and urinary tract; this can result in urinary urgency and poor sitting posture, which can lead to reduced blood circulation, joint and muscle pain, and other health-related issues [2].

1.2 Solution

To solve the problem, our project is a Healthy Chair that alerts the user of their sitting time based on customized input. We will be using a mesh office chair for our project to simulate a realistic scenario. A speech module is used to pre-record our voices and send a variety of messages to alert the user. Two pressure sensor matrices are installed on the chair's seat and back. The user is able to view which pressure sensors in the matrix are activated on the OLED display placed on the desk in front of the chair to get a good understanding of their seated posture. A non-contact IR temperature sensor for the chair's seat and fan are also installed under the mesh office chair. When the user has been sitting for too long, the temperature sensor detects an increase in the chair's seat and the fan will be turned on to cool off the chair. We are using two input and output microcontrollers which interact through Bluetooth. The input microcontroller receives the input signals from the pressure sensors and temperature sensor and transmits the processed data to the output microcontroller. The output microcontroller is connected to the speech module, fan, and OLED display. All of the components of our chair are powered through a rechargeable Lithium-ion battery. This power system can use wall or battery power. Our Healthy Chair targets a common sitting problem that leads to various health issues. It is a user-friendly device and allows its users to set their desired sitting time before our chair warns them to stand up and take a break.

1.3 Visual Aid

Figure 1: Healthy Chair Design and Setup

Figure 2: Mesh Office Chair Example

Figure 1 and 2 are how we envision our final demo will be. Label 1 on the desk is where the OLED display and speaker are placed. Label 2 is where we will place the pressure sensors. Label 3 is where the on-chair system is placed.

1.4 High Level Requirements

- The Healthy Chair must alert the user to stand up using the speech module after the exact time duration inputted by the user through the user interface system
- The OLED display must show the chair seat's temperature and the triggered pressure sensors in real time.
- The Healthy Chair must be able to switch between either a Lithium-ion battery or 120 V AC wall power when the battery is charging.

2. Design

2.1 Block Diagram

The critical subsystems include the data collection, input power, user power, speech, user interface, microcontrollers, and the OLED display. The user power system is responsible for regulating two different voltages to power the entire user interaction system. The input power subsystem is responsible for charging the battery and regulating the voltage supply. The speech subsystem is responsible for recording and playing audio to alert the user when to take a break. The user interface subsystem is how the user will set parameters and interact with the entire chair system. The OLED display is used to show graphical and text to the user. The microcontrollers form the core subsystem since they control the program logic. They also use Bluetooth via HC05 modules to communicate so additional unnecessary wires are removed.

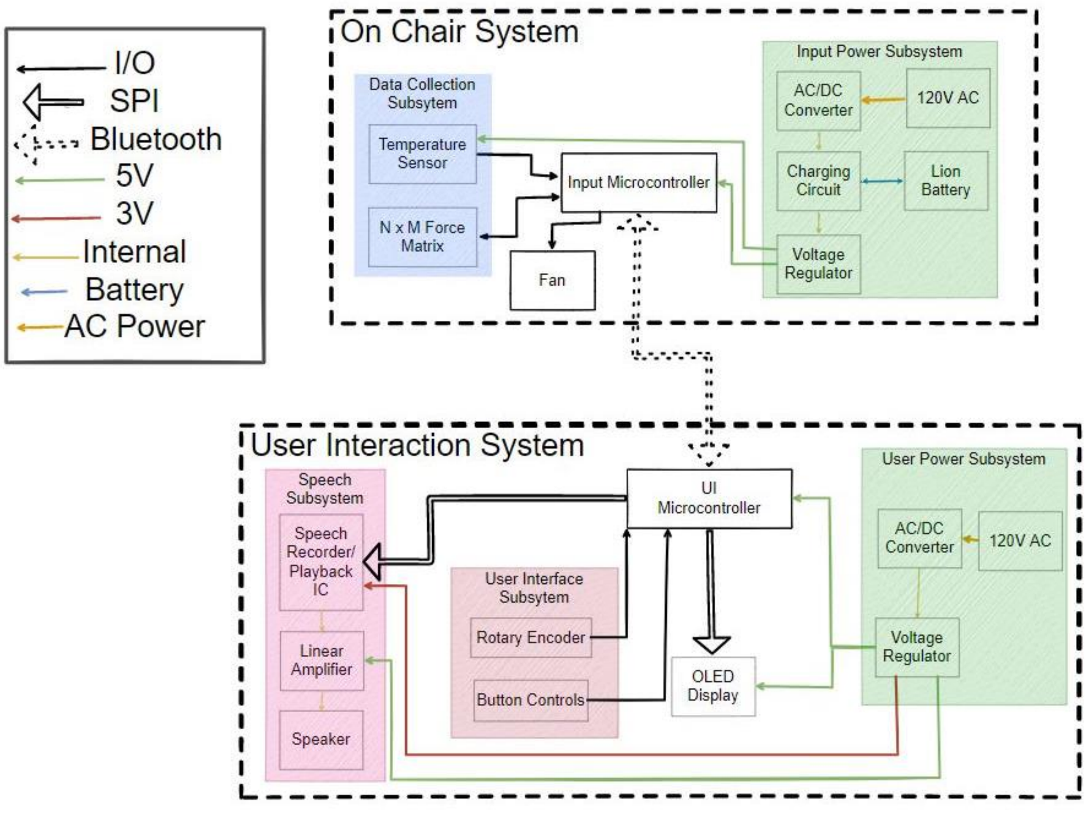

Figure 3: Block Diagram

2.2 Physical Design

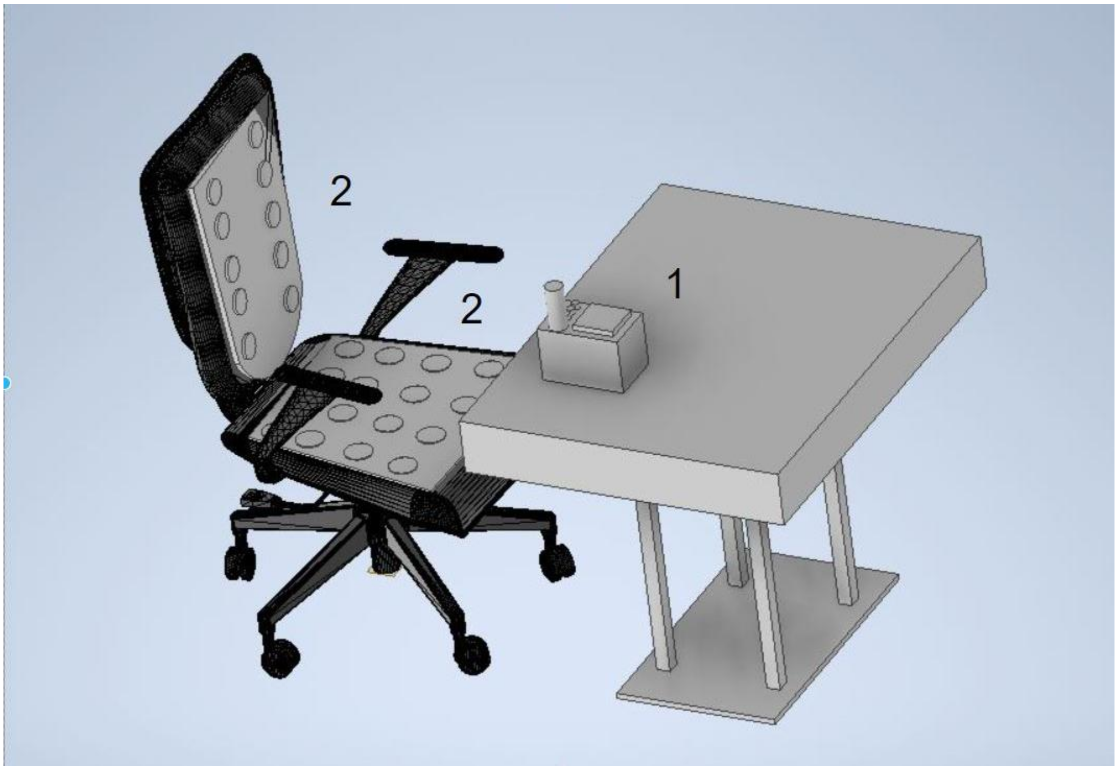

Figure 4: Location of the User Interface System and the Data Collection System

The Healthy chair consists of two independent systems (denoted as "1" and "2") as shown in Figure 4. Label "1" is the user interface system. It has 3 buttons and a rotary encoder for user interaction. There is also an OLED display to communicate necessary information to the user. The microcontroller in the user system is connected to an HC05 Bluetooth module in order to talk to the microcontroller on the chair. The second system, denoted as "2" in the figure, is for data collection. All 24 force sensitive resistors are connected to it as well as the IR non-contact temperature sensor. The microcontroller continuously scans the sensors to get information about how the user is sitting. This microcontroller is also wired to a HC05 Bluetooth module to communicate with the user interface microcontroller.

2.3 On Chair System

2.3.1 Data Collection

First, the data collection subsystem is responsible for collecting data on the user's sitting position. The sensors will be arranged into two separate matrices. There will be a 4x4 matrix on the seat cushion and a 4x2 matrix on the back support of the chair. We will read all the sensor values using a scanning algorithm to reduce the number of pins used by the microcontroller.

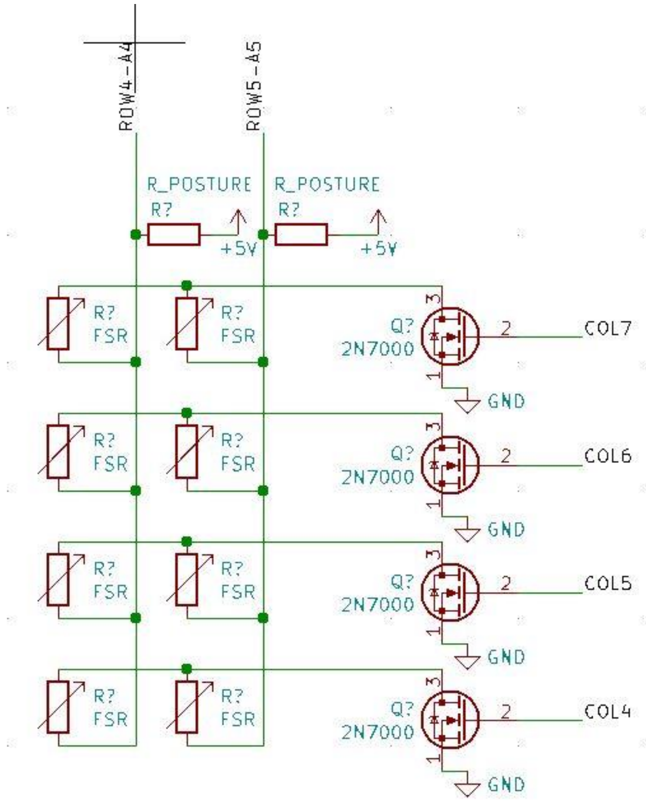

Figure 5: Pressure Sensor Matrix Schematic

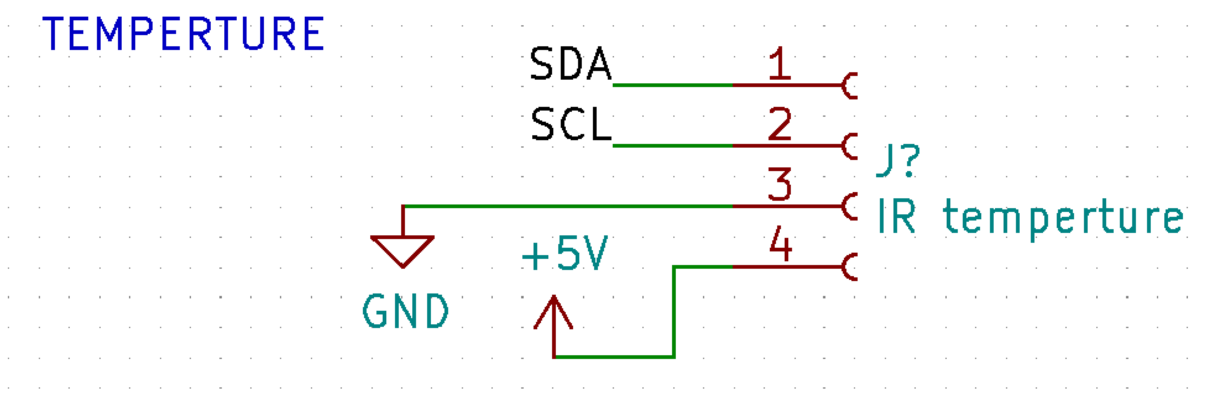

Figure 6: Temperature Sensor Schematic

Figure 5 shows how the back support matrix is arranged. One row of resistors will be enabled while both columns are read simultaneously. This process will continue until each row has been read. We record the voltage level between the pull up resistor and the FSR and compare it to 5 V. The internal ADC has 10 bits of resolution which means the value of the FSR can be mapped between 0 and 1024. The higher the value the less pressure there is on the sensor and vice versa. A value of 1023 means that no one is sitting on the sensor. The other part of the data collection system is the IR temperature sensor. It is connected to the microcontroller via I2C. The temperature sensor can output the object temperature as well as ambient temperature. The Healthy Chair will use this measurement to detect if the user is overheating or has been sitting for too long.

Requirements	Verifications
1. There must be at least 5 different pressure sensing zones. 2. The pressure sensors must respond within 10 milliseconds. 3. The IR temperature sensor must measure the chair seat's temperature with ±0.5°C of accuracy.	1. We will press on the pressure sensors with five increasing values of force and record the voltage across them. We will test for a range from 0-5 V with a 1 V step size. 2. We need to turn on power to the pressure sensors we are trying to test. We start the timer when we provide power. We stop the timer after the ADC has returned its value. We then check to see if the value is returned in under 10 milliseconds. 3. Use a mercury thermometer and place it on the chair seat's surface. Ensure the temperature sensor's output displayed on the OLED screen matches the reading of the mercury thermometer and satisfies Requirement #3.

Table 1: RV Table for Data Collection

2.3.2 Input Power

The on-chair input power subsystem is responsible for providing power to each one of the chair's components. The main source of power is through a 3.7 V Lithium-ion battery. It will be connected to a boost converter so that the necessary 5 V is provided to the temperature sensors and microcontroller. The Lithium-ion battery has a capacity of 2200 mAh and with the total current draw of the on-chair components being less than 100 mA, there should be no issues of power running too low too quickly. In order to keep the battery charged, a charging IC is used to ensure that the nominal battery voltage does not drop below its minimum discharge voltage of 2.75 V. The charging circuit will receive power from an AC/DC wall adapter and USB power.

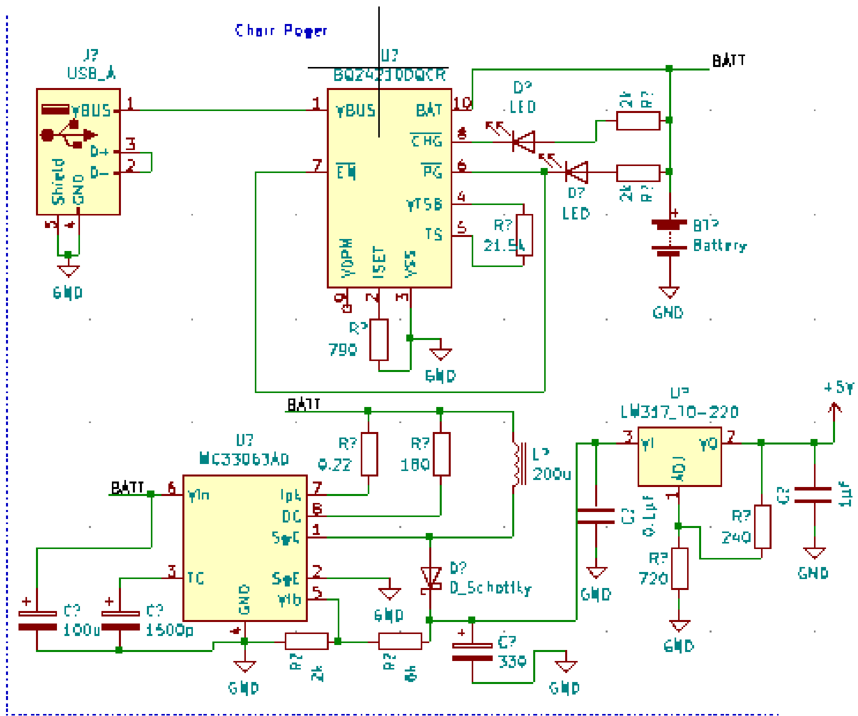

Figure 7: Chair Input Power Schematic

Requirements	Verifications
1. When the battery is being charged, power must be drawn from the wall instead of the battery 2. When the battery is supplying power, the battery does not drop below its discharge voltage of 2.75 V. 3. The battery is stored in a place where the temperature does not exceed its maximum operating temperature	1. Ensure the battery is placed in parallel with the charging circuit output. Use a current probe to measure current leaving the battery when it is being charged and ensure the current is less than 10 mA. 2. Place voltage probes across the positive and negative terminals of the battery. When the system is running, record the voltage of the battery and monitor that it does not fall below 2.75 V.

	3. Once the battery is placed on the chair, measure the temperature with an IR thermometer while the system is running. Monitor that it doesn't not reach 45°C while charging and 60°C when discharging.

Table 2: RV Table for Input Power

2.3.3 Fan

The fan output consists of a fan placed under the chair to cool the user when the chair's seat overheats. It receives its power from the microcontroller via general IO.

Requirements	Verifications
1. The fan must have a noise output of less than or equal to 25dB. 2. The fan must cool off the chair by 1± 0.5 °C within 10 minutes.	1. Measure the noise output of the fan by using a decibel meter and ensure it maintains below our set threshold 2. When the fan is working, use an IR thermometer to measure the chair seat's temperature for 10 minutes and ensure it satisfies Requirement #2

Table 3: RV Table for Fan

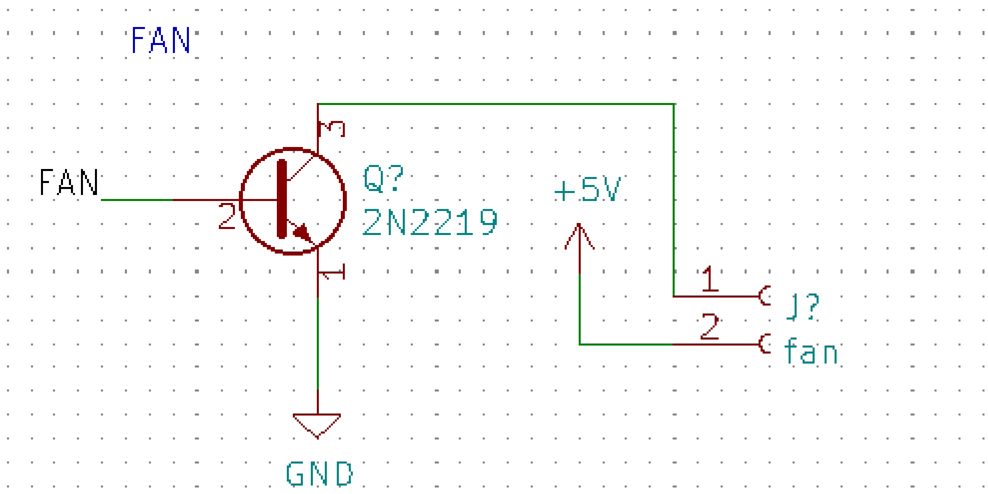

Figure 8: Fan Schematic

2.4 User Interaction System

2.4.1 Speech

Controlled by the microcontroller and powered by the power system, the speech module consists of a voice recording chip, a linear amplifier, a microphone, and a speaker. After it receives an active high signal from the microcontroller, the speech module is able to play our pre-recorded sound to alert the user.

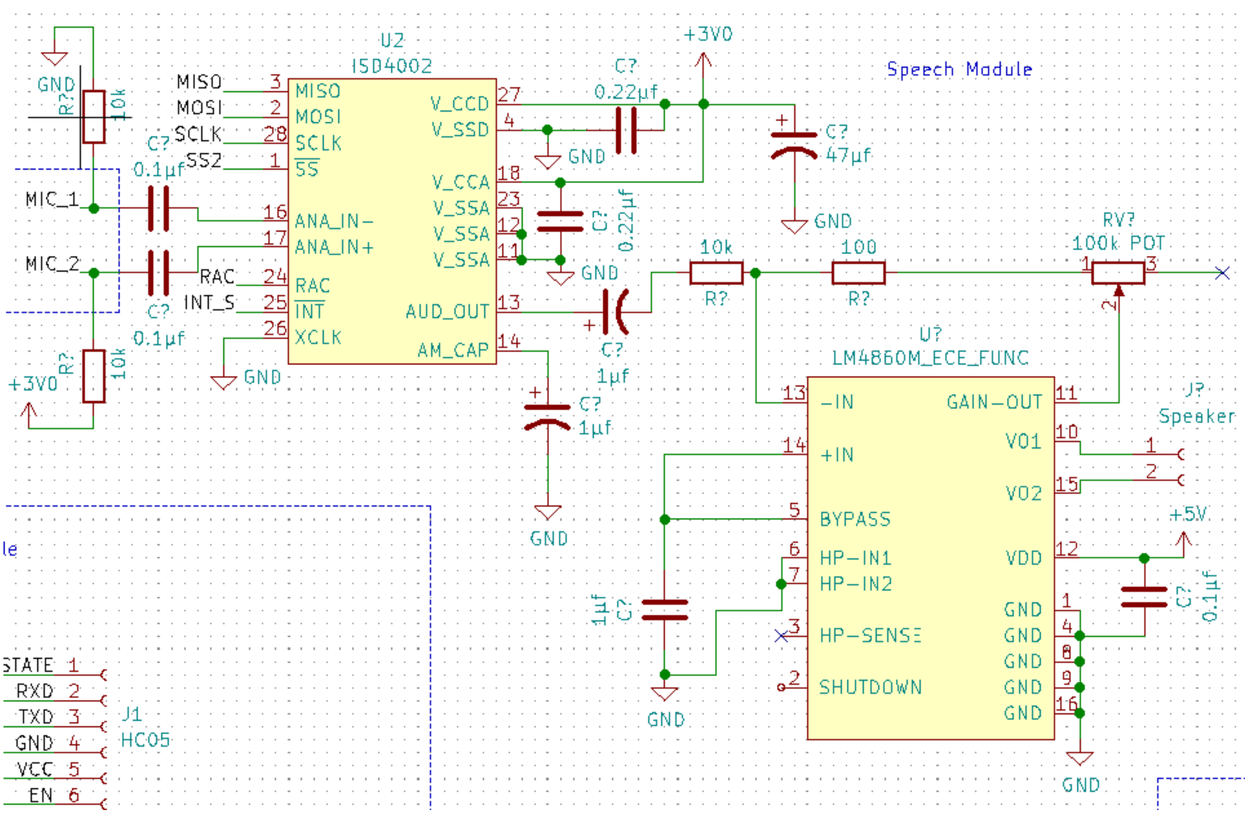

Figure 9: Speech Module Schematic

Requirements	Verifications
1. The ISD4002 voice chip must be provided with a voltage of 3 V ± 10% from the voltage regulator, and the LM4860 linear amplifier must be provided with a voltage of 5 V ± 10% from the power supply. 2. The ISD4002 voice chip must supply an output current of 25 mA ± 10% when recording, and the LM4860 linear amplifier must supply an output	1. Measure output voltages from the ISD4002 voice chip and from the LM4860 linear amplifier using a voltmeter or oscilloscope, and ensure they maintain a steady voltage of 3 V allowing a 10% deviation and 5 V allowing a 10% deviation, respectively 2. Measure output currents from the ISD4002 voice chip and from the LM4860 linear amplifier using an

current of 15 mA ± 10% when playing back the recording. 3. The speech module must record and replay our voices for 20-30 seconds clearly and comprehensively. 4. The speech module must maintain its temperature below 70° C.	ammeter, and ensure they maintain a steady current of 25 mA allowing a 10% deviation and 15 mA allowing a 10% deviation, respectively 3. Record a 25-second speech of warning into the speech module and make sure it can record and accurately play back the recordings 4. When the speech module is working, use an IR thermometer to measure its ambient temperature for 5 minutes and ensure the thermometer's reading satisfies Requirement #4

Table 4: RV Table for Speech Module

2.4.2 OLED Display

The OLED display will be used to let the user know what is going on with the chair. The OLED connects to the microcontroller via SPI. The OLED has a few other IO pins for extra features like reading from an SD card to drawing bitmaps. We will use the OLED display to present menus for user interaction and a graphical representation of how the user is sitting as well as any other pertinent information.

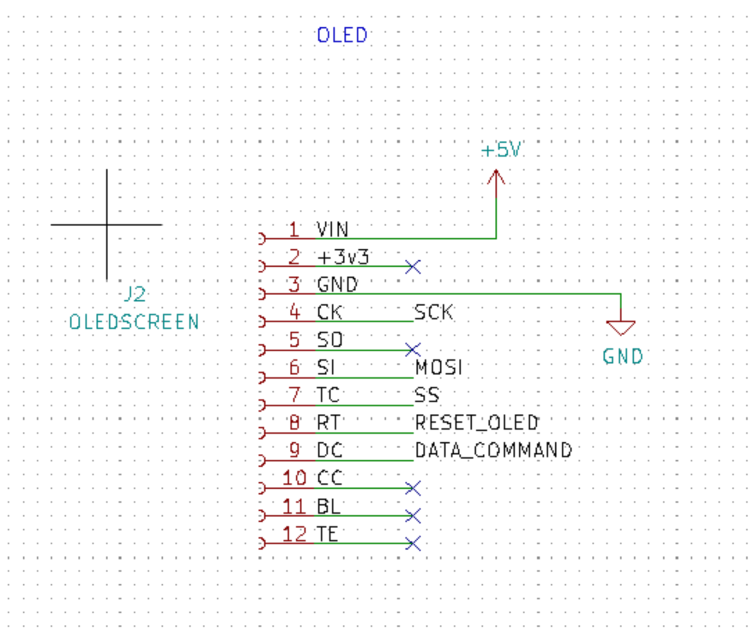

Figure 10: OLED Display Schematic

Requirements	Verifications
1. OLED display should display all pertinent information 2. OLED response time should be within one second from input	1. To verify functionality, we will have to watch the display as we use the chair system 2. To verify we will time when we input something until the screen responds.

Table 5: RV Table for OLED Display

2.4.3 User Power

The user power system is meant to provide constant power to the components that do not live on the chair and are placed on the user's desk. The user power consists of a wall adapter that takes input of 120 V AC and outputs a steady 9 V DC. The OLED display and the speech/speaker system are the two main devices needed to be powered. The OLED display runs at 3 V with an average current draw of 20 mA. The speech/speaker system requires 3 V/33 mA for the speaker unit, 3 V/1 mA for the voice recording IC, and 3 V/7 mA for the amplifier.

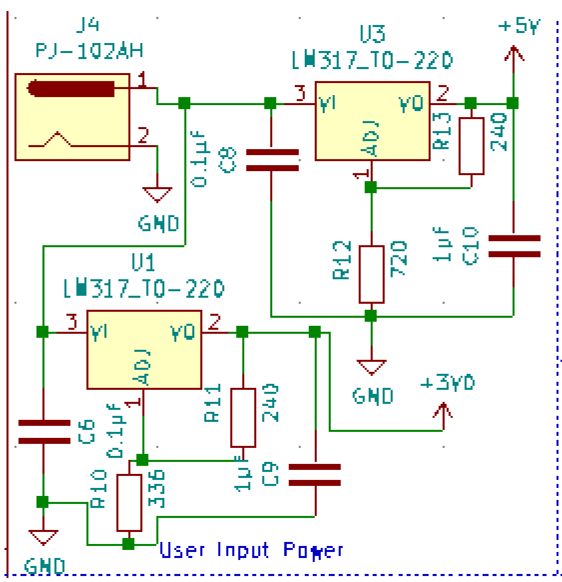

Figure 11: User Power Schematic

Requirements	Verifications
1. Both linear voltage regulators must provide 5 ± 0.5 V and 3 ± 0.3 V 2. Each output of the linear voltage	1. With the load(s) connected to either 3 V or 5 V regulator, the output voltage is measured within 10% of 3 V and 5

regulator must be at least 100 mA	V 2. The output current is connected to a multimeter. The current draw is at least 100 mA for each of the output devices.

Table 6: RV Table for User Power

2.4.4 User Interface

The user interface is what the user will use to provide input for the chair. It will be used to set settings and desired parameters for each user. It consists of 3 buttons and one rotary encoder. It is connected to the microcontroller via general IO. The rotary encoder will be used to set inputs that would be tedious to set with buttons like time and temperature.

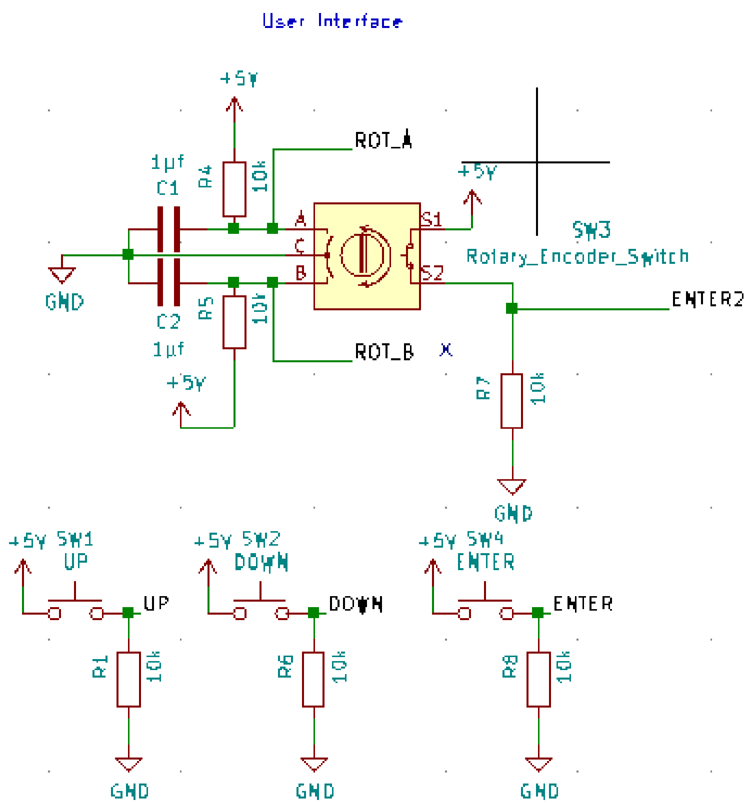

Figure 12: User Interface Schematic

Requirements	**Verifications**
1. All buttons and rotary encoder react to user input.	1. Clicking the buttons and twisting the encoder should change menus and

	settings on the OLED display. The OLED display should react accordingly when a button is clicked.

Table 7: RV Table for User Interface

2.5 Microcontroller Systems

The microcontroller system is the logic unit for the Healthy Chair. We have two ATMEGA1284-PU microcontrollers for both of our systems. The microcontroller on the chair system is responsible for collecting data and sending it over to the user microcontroller. The user microcontroller is responsible for driving all the peripherals including the speech, OLED, and user interface. The two microcontrollers interact via serial port which is connected to the HC05 Bluetooth modules.

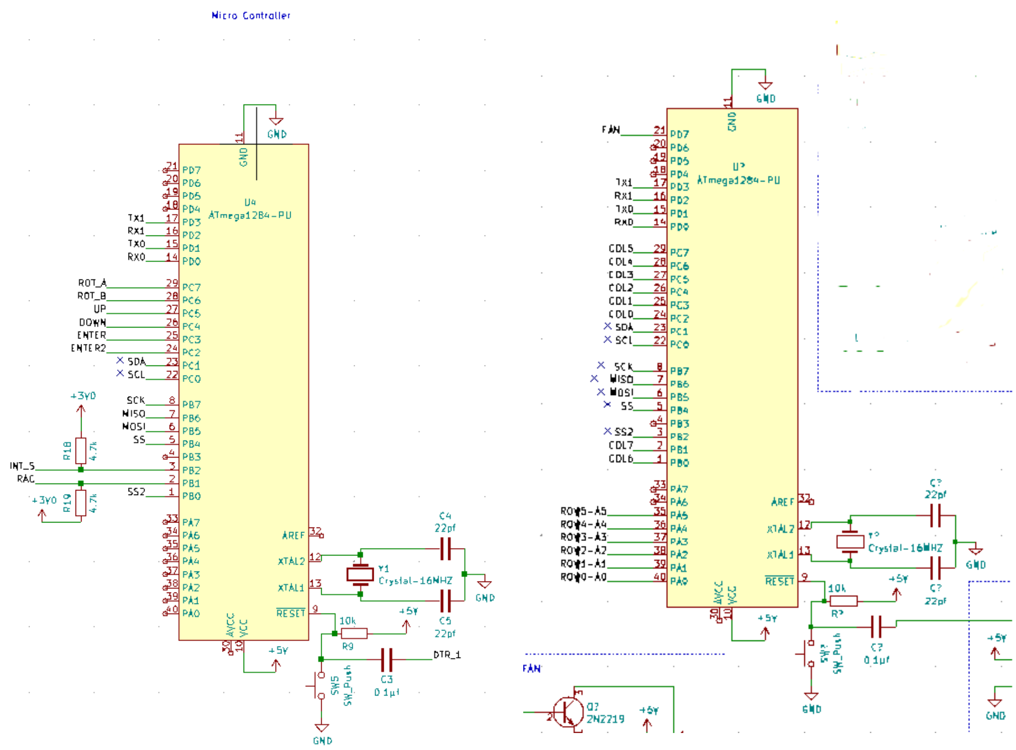

Figure 13: Microcontrollers Schematic

Requirements	Verifications
1. The microcontrollers can communicate via Bluetooth	1. Data will be sent over to the microcontroller every 2 seconds. The OLED display will display how long between every Bluetooth send.
2. User parameters can be changed from the user interface.	2. After a user parameter is changed for example duration of sitting. The microcontroller will act accordingly. Say the time is changed to two minutes, then the chair will alert the user that they have been sitting too long exactly after two minutes. Changing this value again to one minute will verify that we can change and store parameters.
3. Parameters are remembered between power cycles	3. Cycling power to the microcontrollers and then checking the parameter list should display what was set before the power cycle.

Table 8: RV Table for Microcontrollers

2.6 Circuit Schematic

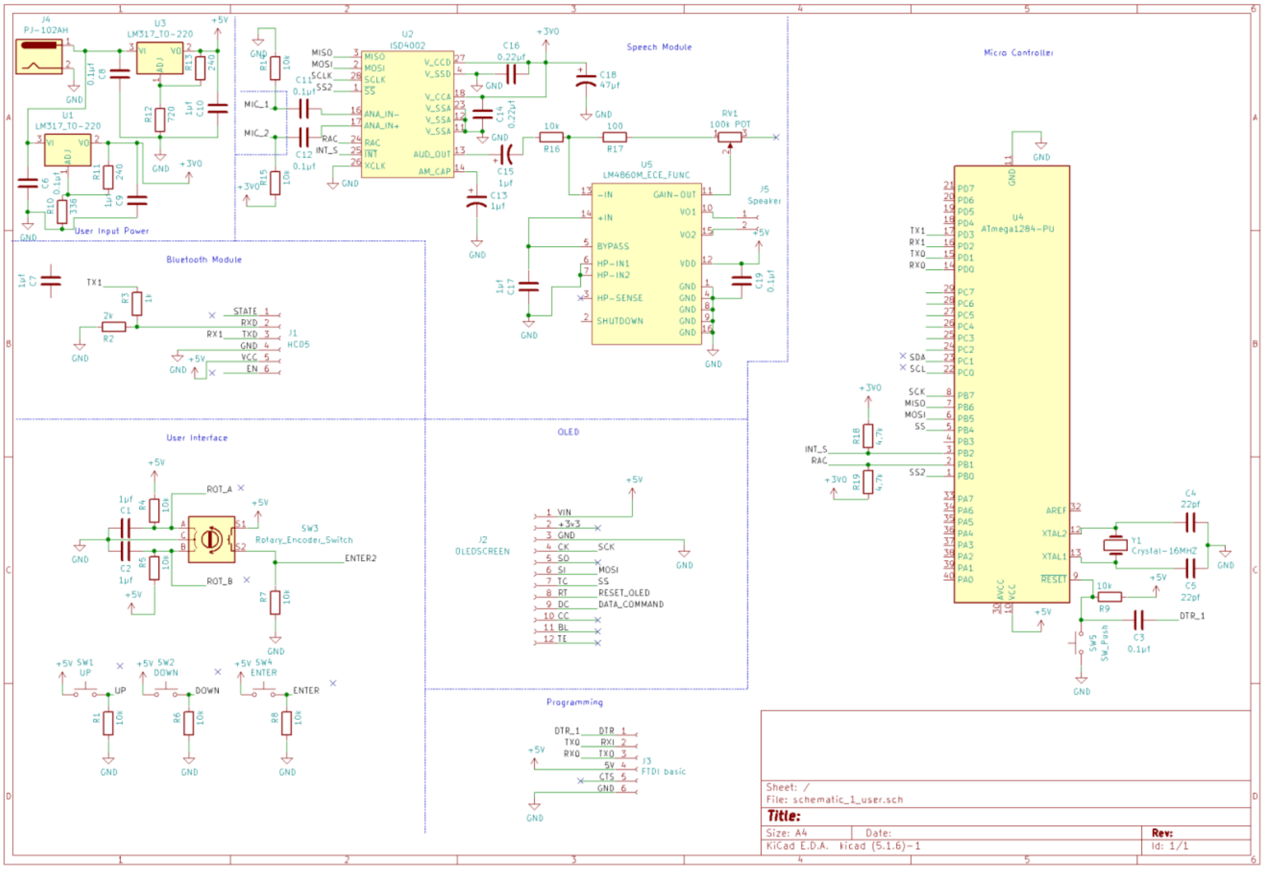

Figure 14: User Interface Schematic

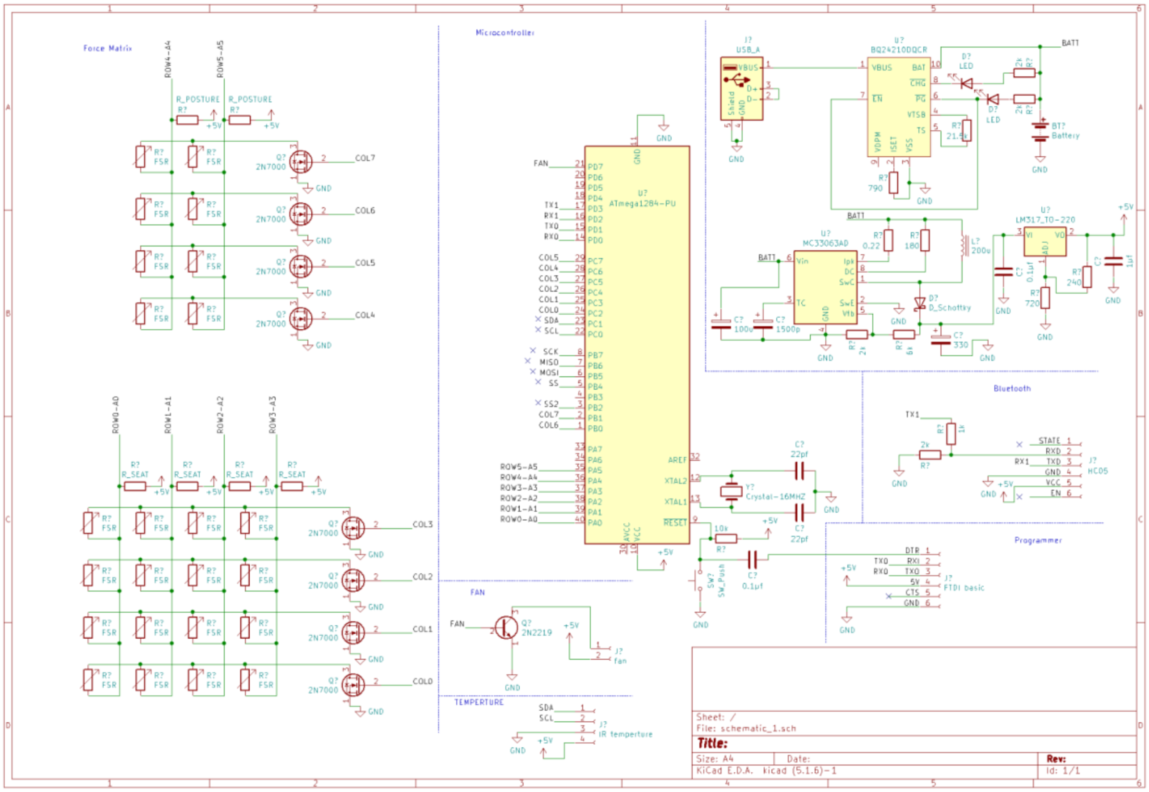

Figure 15: On-Chair Subsystem Schematic

2.7 Tolerance Analysis

The most important factor in the healthy chair is the force sensing matrix and the battery life of the on-chair system. For the pressure sensing matrix, we need to ensure that each individual pressure sensor can give us an accurate data reading within one of our predefined zones. We know that we do not need precise force outputs but we need the force outputs to be accurate when measured relative to the other pressure sensors on the chair. Our ADC has a 10-bit clarity so we can map the force in a range between 0 and 1024. In Figure 15, we see that the resistance profile is on a logarithmic curve. This heavily influences what resistor we use in series. In Figure 16 we see the V_{out} curve is different depending which resistors are used in series. We will need to see what resistor we have to use to have the most differentiable force profile. We also have the schematic flipped in order to use the matrix algorithm and so the V_{OUT} is inverted from that graph. The last thing we need to consider is to choose a large enough resistor in order to conserve battery power. We have 24 pressure sensors that will be running constantly and could end up drawing a lot of power.

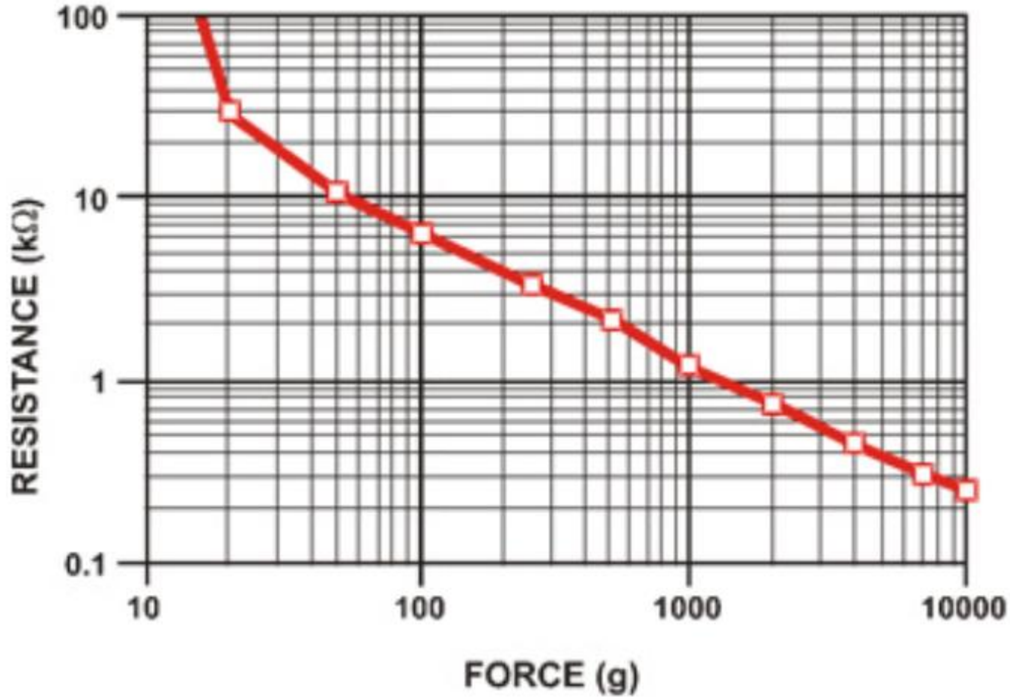

Figure 16: Resistance vs Force Logarithmic Relationship

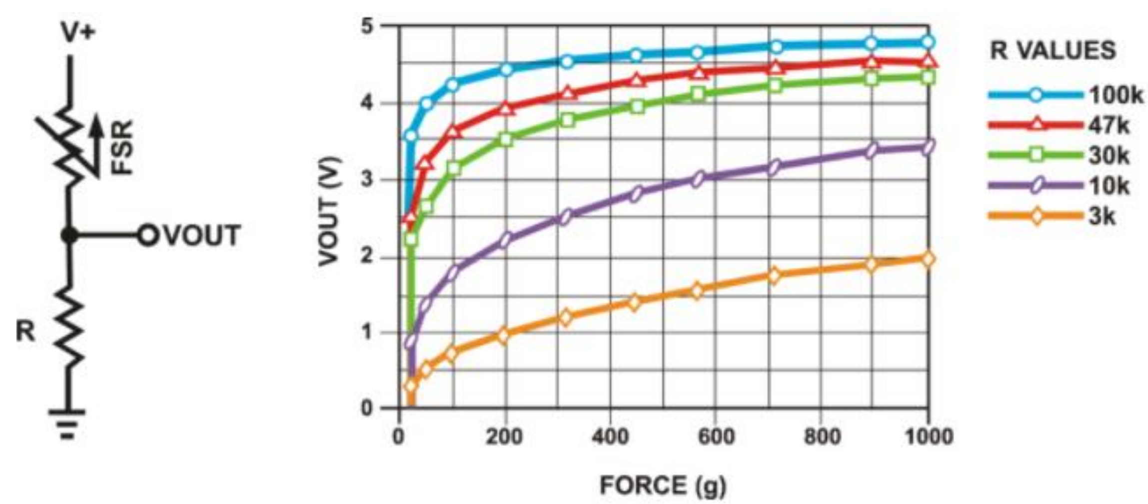

Figure 17: V_{OUT} vs Force with Various Resistor Values

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Parts

Description	Manufacturer	Part #	Quantity	Individual Cost ($)	Bulk Cost ($)
OLED Display	Adafruit	ST7789	1	24.99	24.99
Wire	Adafruit	1528-4730-ND	1	6.95	6.95
Thin Film Pressure Sensor	DFRobot	RP-C18.3-ST	24	5.00	120.00
Bluetooth Module	DEVMO	HC-05	1	19.99	19.99
IR Temperature Sensor	DFRobot	MLX90614	1	16.00	16.00
Microcontroller	Microchip Technology	ATMega1284	2	6.77	13.54
Office Chair	Furmax	/	1	154.98	154.98
Linear Amplifier	Texas Instruments	LM4860M	1	3.08	3.08
Speaker	CUI Devices	CLS0231-L152	1	4.73	4.73
Voice Record IC	Nuvoton	ISD4002-240PY	1	8.59	8.59
Voltage Regulator	Torex Semiconductor	XC6206P302MR-G	1	0.65	0.65
Power Barrel Connector	CUI Devices	PJ-102AH	1	0.81	0.81
Switch Push Button	E-Switch	TL2230OAF 140	1	0.75	0.75
USB Connector	GCT	USB1130-15	1	0.79	0.79
Boost Converter	Texas Instruments	MC33063A	1	0.40	0.40
Lithium-ion Battery	PKCell	1781	1	9.95	9.95
JST Connector	TE Connectivity	440055-2	1	0.26	0.26

Charging IC	Texas Instruments	BQ24210DQCR	1	2.85	2.85
Fan	Sunon Fans	MF40100V2	2	6.01	12.02
Total					**401.33**

Table 9: Materials Cost

3.1.2 Labor

Assuming the salary of labor is $30/hour for each individual, each team member works for an average of 10 hours per week, and there are 16 weeks throughout the spring semester (including spring break since we will also work on the project). Hence, the estimated total labor cost per team member is 30($/hour) * 2.5 * 10(hours) * 16 = $12,000, and the estimated total labor cost for our team is $12,000 * 3 = $36,000.

3.1.3 Total Cost

Combining the costs for labor and parts, our project's sum of costs is estimated to be $36,000 + $401.33 = $36,401.33

3.2 Schedule

Week	Tod	Alan	Ryan
2/14/2022	Research Part Number for Speech Module	Research Part Number for Microcontroller	Research Part Number for Power
2/21/2022	Design Speech PCB circuits/schematics + Work on Design Documentation	Design Microcontroller PCB circuits/schematics + Work on Design Documentation	Design Power PCB circuits/schematics + Work on Design Documentation
2/28/2022	Order Parts and Finalize PCB Design	Order Parts and Finalize PCB Design	Order Parts and Finalize PCB Design
3/7/2022	Research Microcontroller Coding and Test Arrived Components	Research Microcontroller Coding and Test Arrived Components	Research Microcontroller Coding and Test Arrived Components
3/14/2022	Spring Break	Spring Break	Spring Break
3/21/2022	Test Parts and Integrate into Project	Write Test Codes for Microcontroller	Test Parts and Integrate into Project

3/28/2022	Test Parts and Write Individual Progress Report	Test Parts and Write Individual Progress Report	Test Parts and Write Individual Progress Report
4/4/2022	Test Parts and Prepare for Mock Demo	Test Parts and Prepare for Mock Demo	Test Parts and Prepare for Mock Demo
4/11/2022	Finalize Physical Project for Mock Demo	Finalize Physical Project for Mock Demo	Finalize Physical Project for Mock Demo
4/18/2022	Finalize Any Errors from Mock Demo and Prepare for Final Demo	Finalize Any Errors from Mock Demo and Prepare for Final Demo	Finalize Any Errors from Mock Demo and Prepare for Final Demo
4/25/2022	Demo, Give Presentation and Write Final Report	Demo, Give Presentation and Write Final Report	Demo, Give Presentation and Write Final Report

Table 10: RV Table for Input Power

4. Ethics and Safety

Throughout the entire course of our project, we will keep ethics as one of our top priorities. Section I.1 of IEEE code states, “to hold paramount the safety, health, and welfare to the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others”. Our main goal of this project is to ensure the safety and health of people that use our chair. To that end, our chair aims at users who sit for long periods of time, especially with improper posture. We are working to make sure that our chair correctly notifies the user when it is time to take a break from sitting for too long and to let them know if they are sitting unevenly or without proper back support.

A safety concern in our project is the power management system. Our project will involve lithium-ion batteries and utilization of high voltage. Higher voltages are more likely to have greater currents, which proposes an increased risk of injury and death [3]. We will use the one hand method and also make sure to check if anything is connected to power before touching.

Lithium-ion batteries are normally safe when they are used in the right operating conditions, but there have been over 25,000 overheating or fire incidents reported from consumer products in a five-year period [4]. Overcharging occurs when charging still continues when the battery is at full charge. This causes the battery to prematurely age and for current to continue flowing into the battery which can cause overheating, explosion, and fire. We will implement the proper overcurrent protection to ensure that the battery stops charging when it’s full and to make sure that there is no way for the user or anyone around to get shocked.

Since our product is a chair, we consider our product as something that people would want to sit on. Our design is to add pressure sensors in a way that accurately captures the sitting data of the user, but also does not interfere with the user’s comfort. Ideally, we want our project’s users to not feel the pressure sensors, but depending on trial and error, it may be necessary for them to feel them but they will not cause any discomfort.

Section I.5 of IEEE describes working with honest criticism of technical work, to fix any potential errors, make accurate claims, and to properly give credit for people’s contributions. We are always looking for areas to improve and are eager to receive feedback, whether it is positive or negative.

5. References

[1] Harvard Health Publishing, "The dangers of sitting" [Online]. Available at: https://www.health.harvard.edu/pain/the-dangers-of-sitting
[2] Global News, "Sitting all day at work? Get up every 30 minutes to cut your risk of death"[Online]. Available at: https://globalnews.ca/news/3740438/sitting-all-day-at-work-get-up-every-30-minutes-to-cut-your-risk-of-death/
[3] Division of Research Safety, "Electrical Safety In the Research Laboratory" Division of Research Safety Library [Online]. Available at: https://drs.illinois.edu/Page/SafetyLibrary/ElectricalSafetyInTheResearchLaboratory

[4] Occupational Safety and Health Administration, "Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices" [Online]. Available at: https://www.osha.gov/sites/default/files/publications/shib011819.pdf